MANUAL OF

OPERATION AND MAINTENANCE

INSTRUCTIONS

for

TLM-22
AIRBORNE TELEMETRY ANTENNA SYSTEM

CONTRACT AF 08(606)-1978

AIR FORCE MISSILE TEST CENTER
PATRICK AIR FORCE BASE, FLORIDA

DYNATRONICS, Inc.

30 DECEMBER 1957

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SECTION I

GENERAL DESCRIPTION

1-1. The Airborne Telemetry Antenna System is designed to operate in conjunction with a sensitive airborne receiving-recording system for receiving radio telemetry signals from 216 through 260 megacycles. It consists of a circularly-polarized, omni-directional antenna, and a cylindrical fiber glass radome.

1-2. The antenna is a double swastika configuration as shown in Figure 8-1. This arrangement results in four separate radiating dipoles tilted 30° from the horizontal. Correct polarization and phasing is achieved by proper orientation of the several elements as explained under Theory of Operation. The radiated signal input is terminated in a single coaxial connector at the top of the supporting column.

1-3. The antenna is designed to match an impedance of 51 ohms and to result in a voltage standing wave ratio of less than 2 to 1 on the transmission line to the receiving system over the specified frequency range. The axial ratio (ellipticity of polarization) of the circularly-polarized antenna is less than 1.1:1 for all frequencies above 235 mc, and does not exceed 1.3:1 at 216 mc.

1-4. The antenna system is designed for installation on Type C-54 military aircraft and will withstand, without damage or degradation of performance, speeds equivalent to the design limit diving speed of the C-54 aircraft, and changes in air pressure as encountered in flight at any service altitude of said aircraft.

1-5. The radome is so designed and installed that in any position of the antenna while the aircraft is in flight, or on the ground, no water or other liquid will collect in any portion of the system.

1-6. The system with which the antenna works is used to receive signals over ranges from 10 to 50 nautical miles and at altitudes 5,000 feet and above. The field strength pattern of the installed system is essentially omni-directional in the horizontal plane with a minimum of deep nulls. While the direction of maximum gain is essentially in the horizontal plane, normal gain and fewer nulls in the horizontal patterns may be realized at elevation angles of -5 and -10 degrees.

SECTION II

THEORY OF OPERATION

2-1. INTRODUCTION

The TLM-22 Telemetry Antenna is designed for right-handed (clockwise) circular polarization. Circular polarization is actually a special case of elliptical polarization where the electrical field vectors E_1 and E_2 displaced by 90 degrees are equal. Since true circular polarization can only be achieved in the ideal case, the term "elliptical polarization" will be used for the following discussion.

2-2. ELLIPTICAL POLARIZATION GENERAL THEORY

In the design of this system, elliptical polarization is produced by two linearly-polarized waves of the same frequency. Assume that both waves are travelling in the positive Z direction and that one plane of polarization is in the X direction and the other in the Y direction as in Figure 2-1.

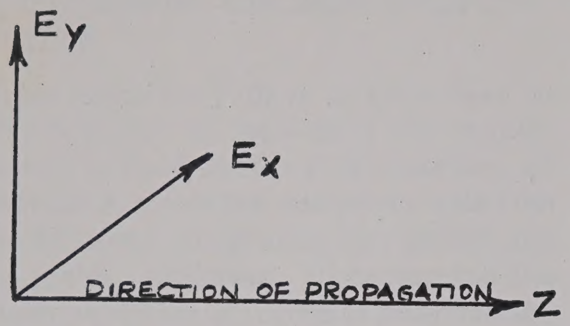


FIGURE 2-1

If X is horizontal, the wave with E in the X direction may also be called a horizontally-polarized wave, and the wave with E in the Y direction a vertically-polarized wave. Let the instantaneous electric field of the horizontally-polarized wave be designated E_x and the instantaneous electric field of the vertically-polarized wave be designated as E_y. Then as a function of time and distance,

$$E_x = E_1 \sin (wt - \beta Z) \qquad (1)$$

$$E_y = E_2 \sin (wt - \beta Z + \alpha) \qquad (2)$$

where E_1 = amplitude of horizontally-polarized wave, E_2 = amplitude of vertically-polarized wave and
α = time-phase angle by which E_y leads E_x (with E_x taken as reference).
The component of the field in the Z direction is everywhere zero ($E_z = 0$). With $E_z = 0$, these equations can be proved to represent the parametric equations of an ellipse, as follows:

$$E_x = E_1 \sin wt \qquad (3)$$

$$E_y = E_2 \sin (wt + \alpha) \qquad (4)$$

where wt is the independent variable. Equation (4) is first expanded to

$$E_y = E_2 (\sin wt \cos\alpha + \cos wt \sin\alpha). \qquad (5)$$

Equations (3) and (4) can also be written

$$\sin wt = \frac{E_x}{E_1} \quad \text{and} \qquad (6)$$

$$\cos wt = \sqrt{1-\sin^2 wt} = \sqrt{1-\frac{E_x}{E_1}^2} \qquad (7)$$

Substituting (6) and (7) in (5), rearranging and squaring,

$$\frac{E_x^{\;2}}{E_1^{\;2}} - \frac{2E_xE_y\cos\alpha}{E_1E_2} + \frac{E^2_{\;y}}{E_2} = \sin^2\alpha \qquad (8)$$

When E_x and E_y are in time-phase quadrature,

$$\alpha = \left(\frac{1 + 2K}{2}\right)\pi$$

Where K = 0, 1, 2, 3, etc., the middle term of equation (8) drops out and reduces to

$$\frac{E^2_{\;x}}{E^2_{\;1}} + \frac{E^2_{\;y}}{E^2_{\;2}} = 1 \qquad (9)$$

which is the standard form of the equation for an ellipse (axis coincident with coordinate axis) as shown in Figure 2-2.

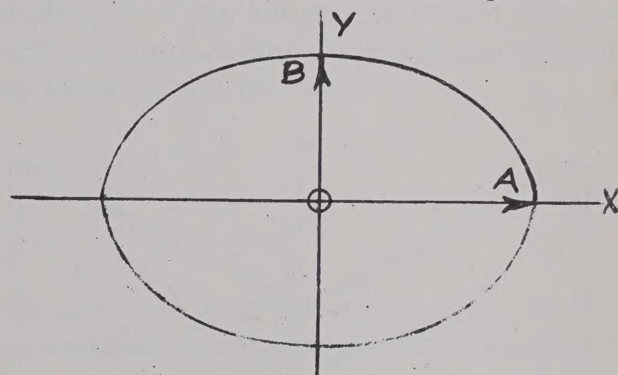


FIGURE 2-2

The line segment OA is the semi-major axis, and the line segment OB is the semi-minor axis of the ellipse. The ratio OA to OB is called the axial ratio of the polarization ellipse. In the special case of $E_1 = E_2$, equation (9) becomes

$$E^2_{\;x} + E^2_{\;y} = E^2_{\;1} \qquad (10)$$

which is the equation for a circle. Thus, when two linearly-polarized component waves are in time-phase quadrature and also equal in amplitude, the resultant wave is circularly-polarized.

2-3. CLOCKWISE CIRCULAR POLARIZATION

From equation }10) it is seen that at a fixed position on the Z axis the resultant electric field vector E is constant in magnitude and rotates uniformly with time in the X-Y plane completing one revolution each cycle. However, to determine the rotation direction for circular polarization where $\alpha = \left(\frac{1 + 2k}{2}\right)\pi$ and $E_1 = E_2$, equations (3) and (4) are rewritten as follows:

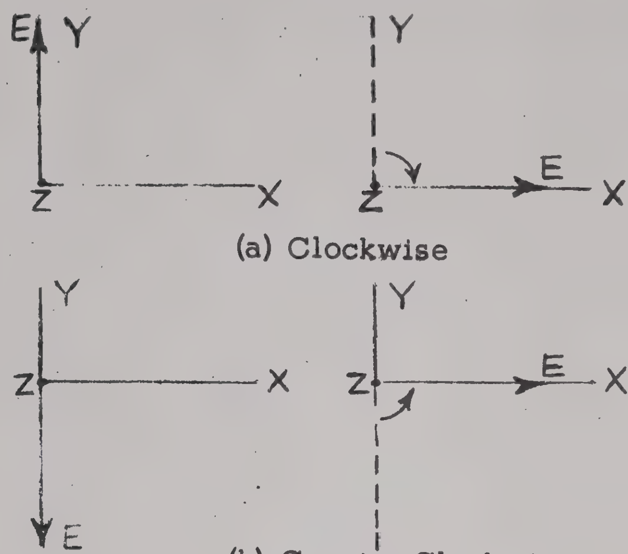
$$E_x = E_1 \sin wt \tag{11}$$

$$E_y = \pm E_1 \cos wt \tag{12}$$

the polarity of (12) being positive when k is even and negative when k is odd.

Consider first the case when $\alpha = \frac{\pi}{2}$, $\frac{5\pi}{2}$ etc. When $t = 0$, $E_x = 0$ and $E_y = +E_1$ so that E is in the positive Y direction. One-quarter of a cycle later $E_x = +E_1$ and $E_y = 0$ so that E is in the positive X direction. Thus, at a fixed position on the Z axis, the resultant electric field vector E rotates in a clockwise direction as illustrated in Figure 2-3a. For the case when $\alpha = \frac{3\pi}{2}, \frac{7\pi}{2}$, etc. and $t = 0$, $E_x = 0$ and $E_y = E_1$ so that E is in the negative Y direction. One-quarter cycle later $E_x = +E_1$ and $E_y = 0$ so that E is in the positive X direction. Hence, at a fixed position on the Z axis, the resultant electric field vector E rotates in a counter-clockwise direction as illustrated in Figure 2-3b.

According to the I.R.E. standards, "clockwise circular polarization receding" is called "right-circular polarization" which also has a definite relationship to helical beam antennas. It is seen, then, that direction of propagation of the rotating vectors in Figure 2-3 is into the page for clockwise polarization.



(a) Clockwise

(b) Counter Clockwise

FIGURE 2-3

2-4. TILTED SWASTIKA CONFIGURATION

For the particular swastika configuration which this antenna takes, an analysis of the manner in which a horizontally approaching wave induces current in the antenna follows:

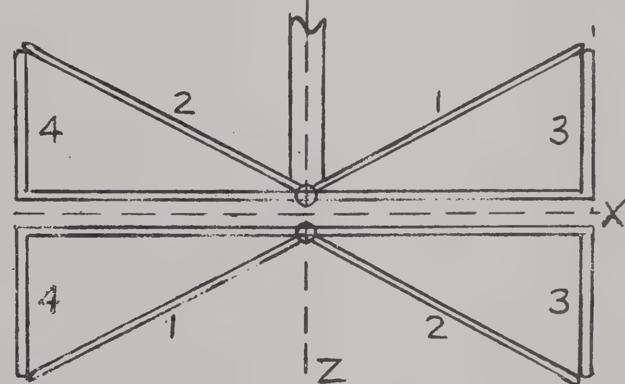


FIGURE 2-4

Referring first to Figure 2-4, the elements 1-1, 2-2, 3-3 and 4-4 are each 60 electrical degrees from the center of the assembly (Z axis) and are tilted 30° with respect to horizontal. First, assume a wave approaching the antenna along the Y axis into the page. The reference point is the electrical phase center, or in this case, the X axis in the X-Y plane (Figure 2-5).

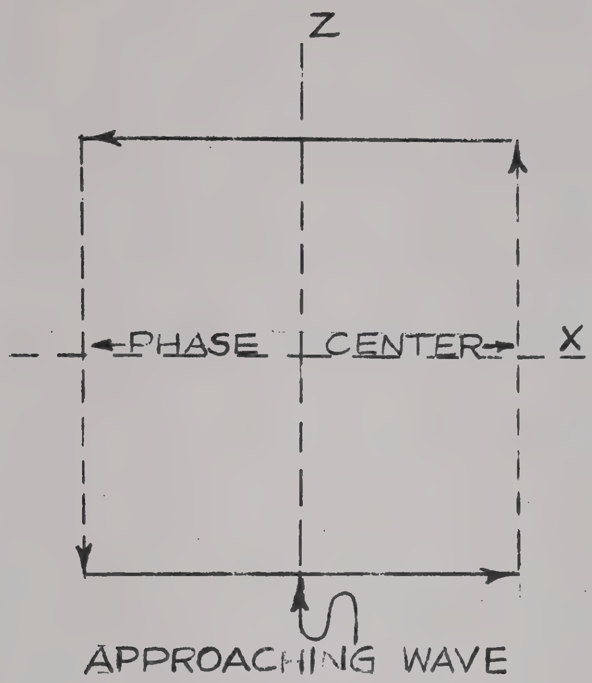


FIGURE 2-5

It will be seen from Figure 2-6 below

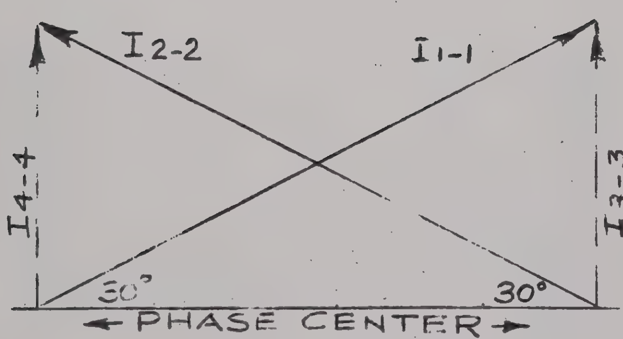


FIGURE 2-6

that the currents induced yield voltages with the following relationships:

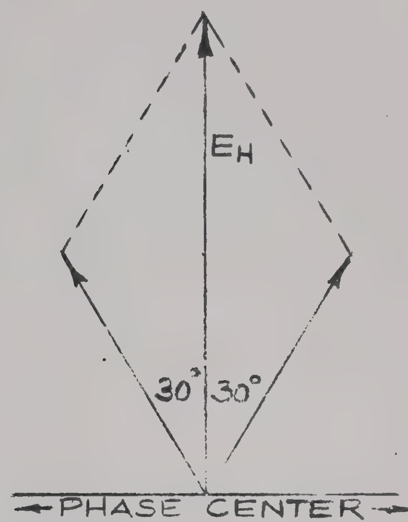


FIGURE 2-7

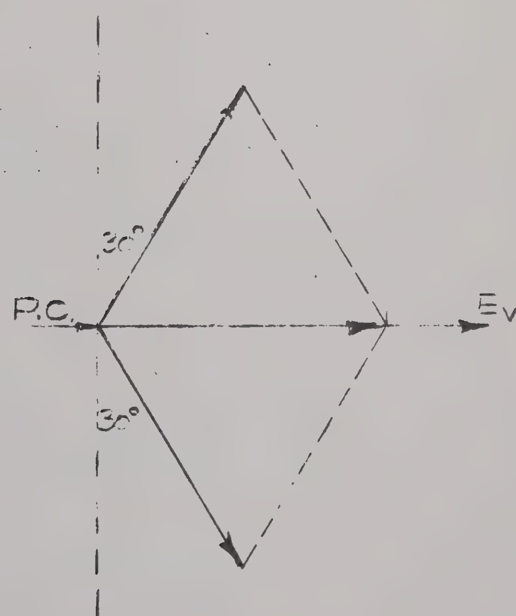


FIGURE 2-8

$$E_H = 2\cos^2 30^\circ \angle 90^\circ$$

$$E_V = 2\sin^2 30^\circ \angle 0^\circ + 2\sin 30^\circ \angle 0^\circ$$

Reducing to numerical form:

$$E_H = 2\left(\frac{\sqrt{3}}{2}\right)^2 = 2 \times 3/4 = 1\ 1/2$$

$$E_V = 2(1/2)^2 + 2 \times 1/2 = 1/2 + 1 = 1\ 1/2$$

These results show, then, that the basic requirements of phase and magnitude for circular polarization are satisfied.

Since the antenna configuration is symmetrical, it follows that the same equations will hold for other approaching waves around the azimuth plane. From the practical standpoint, the circularity of the antenna pattern, particularly for horizontal polarization, is modified by the ground plane effect of the aircraft.

SECTION III

INSTALLATION

3-1. The TLM-22 Antenna System is designed for installation on the under fuselage of Type C-54 aircraft. Figures 8-3 and 8-4 show most of the dimensional and installation details. The antenna proper and its adapter plate weigh 7 pounds. The radome weighs 29 pounds and its adapter assembly 5 pounds.

3-2. As indicated on the schematic drawing, Figure 8-4, a doubler plate arrangement for both antenna and radome is recommended. Doublers should be 2024 T-3 aluminum alloy at least .0625" thick and should be integrally-riveted to the skin around the areas to which the antenna and radome will be attached.

3-3. The contour of the two adapters mates that of the under fuselage at Station 529. Since the antenna and radome are easily removable from their respective adapters, they can be used on aircraft other than the C-54 by designing new adapter assemblies. Since the installation discussed in this manual is specifically for the C-54, further discussion is limited to this type aircraft.

3-4. The following steps are listed for a simple and efficient airborne installation:

a. Locate reference mark at Station 529 on the under skin at the fuselage center line (Buttock line 0).

b. Cut hole in the aircraft skin and doubler 2-3/8" in diameter.

c. Remove antenna from adapter plate. Center adapter plate around cutout and line drill six equally-spaced #H (.266) holes on a 2-5/8" radius from the center of adapter assembly.

NOTE

Although the general contour of the adapter plate will approximately orient it around the vertical axis, it is important to line up diametrically opposite anchor nuts so that they fall on fuselage centerline.

d. Secure adapter to fuselage using 1/4"-28 x 29/32" long stainless or cadmium plated steel hex bolts (AN 4-10A) and elastic stop nuts (AN 363-428).

e. Reinstall antenna on adapter plate with the six hex bolts provided. It will be seen that the antenna is now oriented so that the four sets of dipoles look out at 45° with respect to the longitudinal and transverse axis of the aircraft.

f. Next, slide the complete radome assembly over the installed antenna and fit the contoured adapter to the under skin. Adjust the assembly fore and aft and from left to right so that the radome is approximately centered around the antenna. Locate this position by marking around the outer periphery of the adapter flange. Now lower the assembly, and remove the radome from the adapter.

g. Place the adapter back against the fuselage, locating as under f, above.

h. Line drill 24 equally-spaced #7 (.201) holes through the outer flange and reinforced aircraft skin.

NOTE

It may be necessary to stagger some holes in order to clear stringers.

i. Secure adapter to fuselage using 10-32 x 29/32" long stainless or cadmium plated steel truss-head screws and elastic stop nuts (AN 363-1032). (A suitable sealing compound should be used between adapter flange and skin).

j. Reinstall radome on adapter assembly, using the 10-32 screws provided. Screws should be drawn up snugly so that the foam rubber seal will provide a moisture free fit.

k. A small hole about 1/8" in diameter should be drilled in the bottom center of the radome to allow for drainage of water that may collect in the radome.

3-5. The mechanical installation is now complete. Precaution should be taken that no liquid is allowed to collect on the inner fuselage area above the antenna support column. If this cannot be guaranteed, a suitable sealant should be placed in the void just above the antenna adapter plate.

3-6. Electrical connection to the receiving system is made through an N-type connector at the top of the antenna support column and is accessible through the fuselage cutout discussed above. A UG-21B/U connector should be used as the mating plug.

SECTION IV

OPERATION

4-1. The antenna system operates as part of the telemetry receiving system. Once connected and tested with the system, no further operation or adjustment is required. Converting the scale model and flight test data to the actual operating conditions at AFMTC for the limiting range (50 miles) and altitude (5,000 feet), the signal margin at the receiver input is 29 db for the best coverage condition and 13 db for the weakest (deepest null) condition. Operational tests of the system in the final C-54 configuration should be made to confirm these results. Because of the ground plane effect of the aircraft skin, signal strength on the vertically-polarized waves is somewhat stronger than the horizontally-polarized waves, particularly at the low elevation angles.

4-2. Optimum performance will be realized with the aircraft in level flight. If necessary to change course or altitude during a data gathering run, abrupt changes should be avoided. While the antenna is designed for maximum gain in the horizontal plane, good reception can be realized to at least -10 degrees (equivalent to 10 miles at 10,000 feet). There is, however, a diminishing gain from this point on to -90° (directly below aircraft) where, theoretically, the pattern nulls out to zero.

SECTION V

RANGE MAINTENANCE

5-1. The nature of this installation on a USAF aircraft operating from the home base (PAFB) is such that no range maintenance will be required.

SECTION VI

BASE MAINTENANCE

6-1. Since this equipment is firmly attached to the aircraft and has no moving parts, the extent of Base Maintenance is minor. Although designed for maximum resistance to environmental factors, an inspection procedure for preventative maintenance is recommended. The radome should be removed from its adapter assembly once each year so that the antenna can be checked for mechanical tightness and freedom from oxidation or other surface contamination, and the radome may be drained of water that was not removed by normal drainage.

CONTRACT NO. AF 08(606)-1978
CONTRACTOR: Dynatronics, Inc.

PROVISIONING PARTS BREAKDOWN

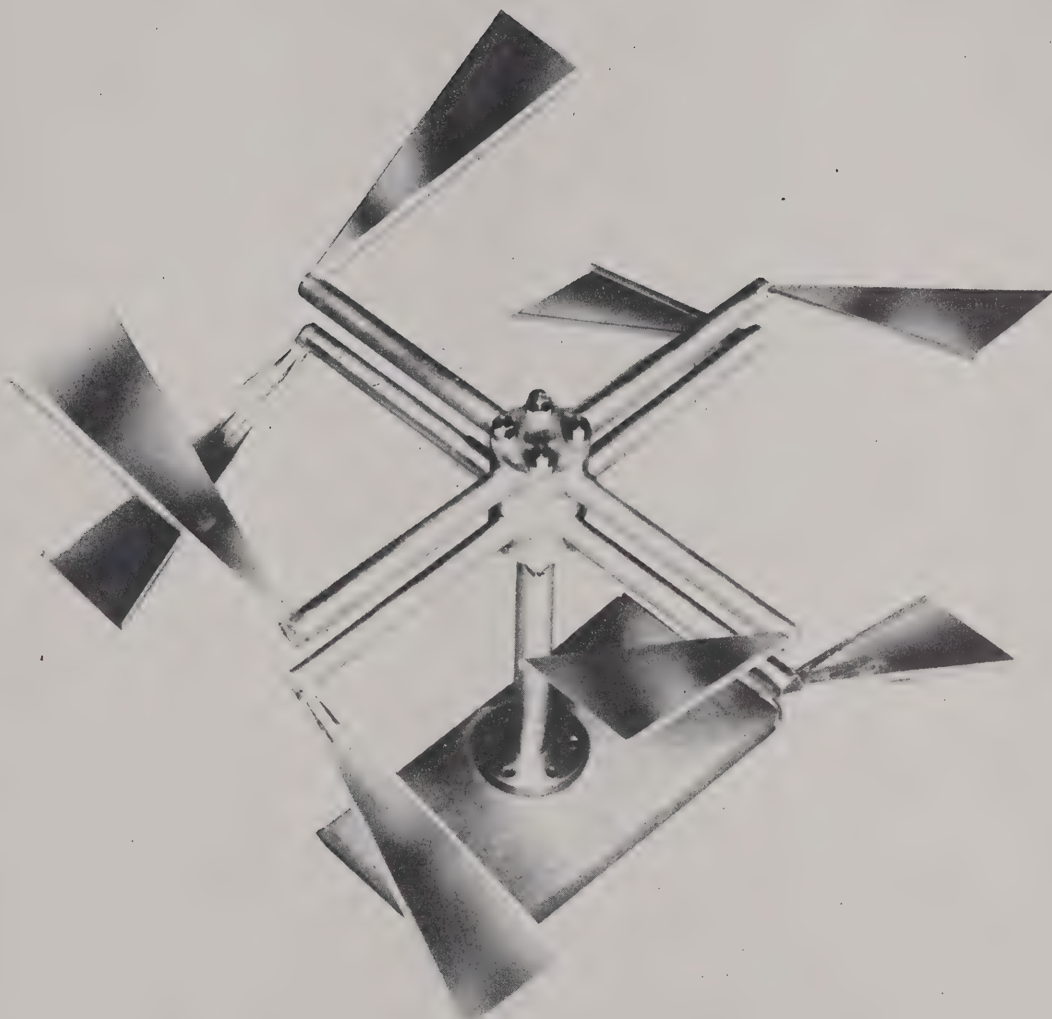
PRODUCTION LIST

Item No.	Reference Designator	Class	Stock Number	Mfg. and Part No.	Description 1 2 3 4 5 6 7	Unit per Assy.	Procure-ment Code	Unit Cost	Remarks
1	None			Dynatronics, Inc. Part #D3002-1	Antenna, circularly polarized (clockwise), to operate between limits of 216 through 260 mcs., impedance 50 ohms., VSWR less than 2 to 1, axial ratio less than 1.26 to 1.	1			
2	None			Dynatronics, Inc. Part #D3002-2	Adapter Plate, antenna.	1			
3	None			Dynatronics, Inc. Part #D3002-3	Radome, glass fabric cloth, Fabric #181 per MIL-P-8013A Type III with Volan A finish, impregnating resin-selectron 5016, per MIL-R-7575A except temperature range to be -65°F to 300°F.	1			
4	None			Dynatronics, Inc. Part #D3002-4	Adapter assembly, radome, aluminum alloy.	1			
5	None			Dynatronics, Inc. Part #D3002-5	Ring, cap, aluminum alloy.	1			

SECTION VIII

DIAGRAMS

DRAWING LIST



PICTORIAL OF ANTENNA

FIGURE 8-1

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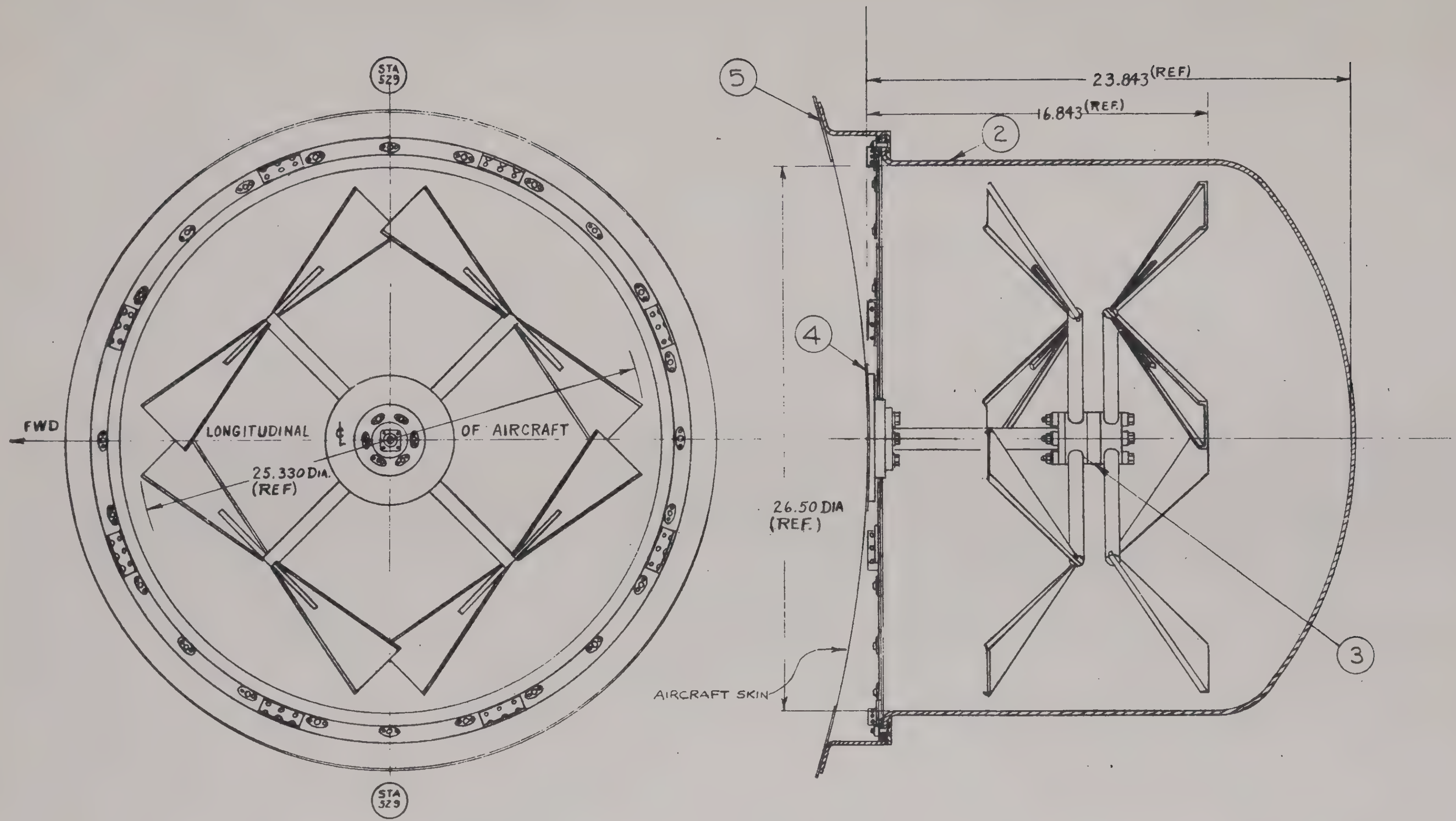
PICTORIAL OF RADOME

FIGURE 8-2



1 GEN'L ARRGT.

REQD	ITEM	PART NO	DESCRIPTION
	5	REF	OUTER DOUBLER PLATE
	4	REF.	ANTENNA DOUBLER PLATE
1	3	D-56368	ANTENNA ASSY.
1	2	C-56391	RADOME ASSY
X	1	C-56367	ANTENNA ASSY ARR'G'T.
	LIST OF MATERIAL		

FIGURE 8-3

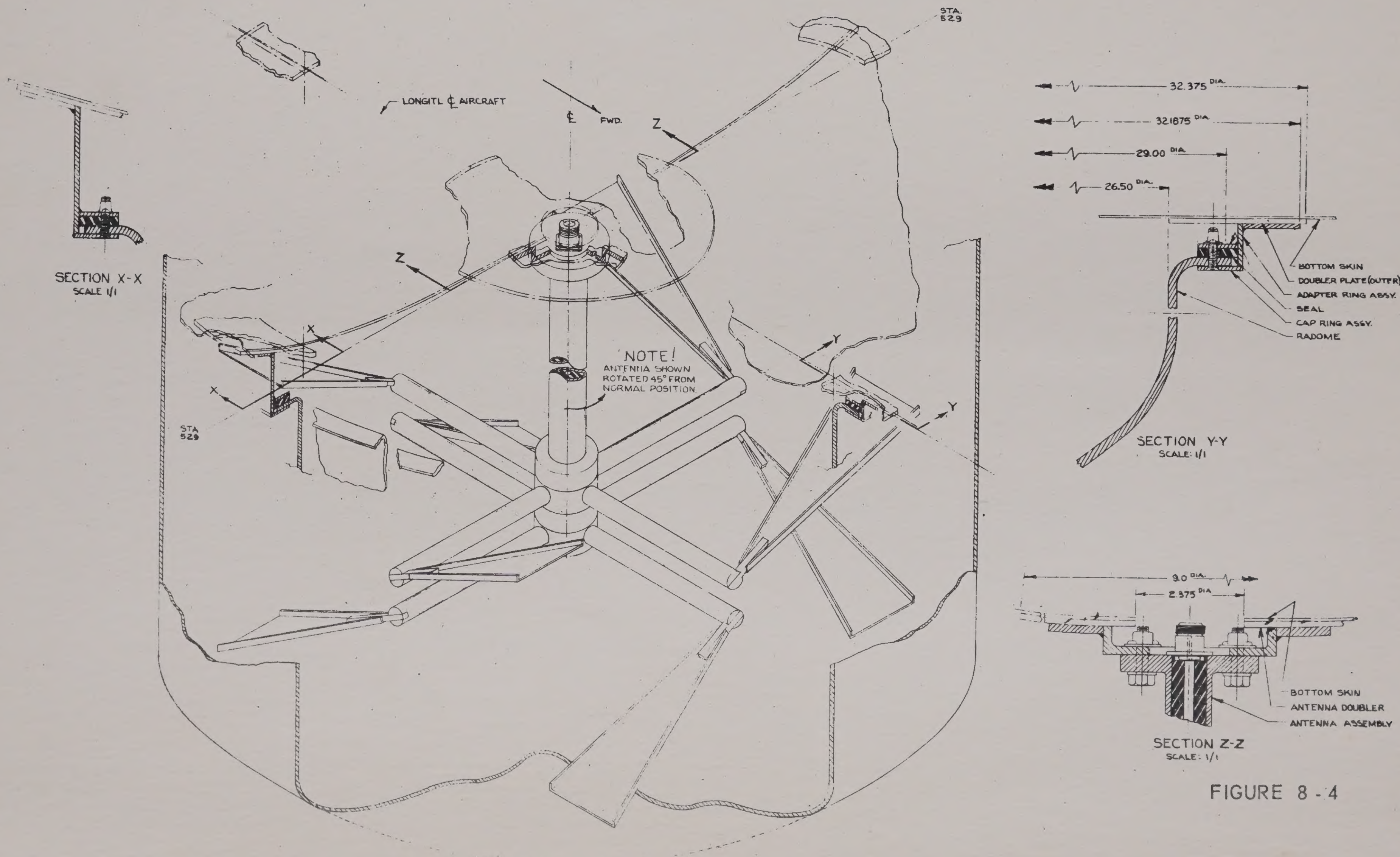

SECTION X-X
SCALE 1/1
LONGITL ℄ AIRCRAFT
℄
FWD.
Z
Z
X
X
STA 529
STA. 529
Y
Y
NOTE!
ANTENNA SHOWN
ROTATED 45° FROM
NORMAL POSITION.
32.375 DIA.
32.1875 DIA.
29.00 DIA.
26.50 DIA.
BOTTOM SKIN
DOUBLER PLATE (OUTER)
ADAPTER RING ASSY.
SEAL
CAP RING ASSY.
RADOME
SECTION Y-Y
SCALE: 1/1
9.0 DIA.
2.375 DIA.
BOTTOM SKIN
ANTENNA DOUBLER
ANTENNA ASSEMBLY
SECTION Z-Z
SCALE: 1/1

FIGURE 8 - 4